

# **MSFC Natural Environments Branch Analysis of 19 November 2016 Difference in Tropospheric Doppler Radar Wind Profiler and Balloon Wind Profiles During a Launch Countdown**

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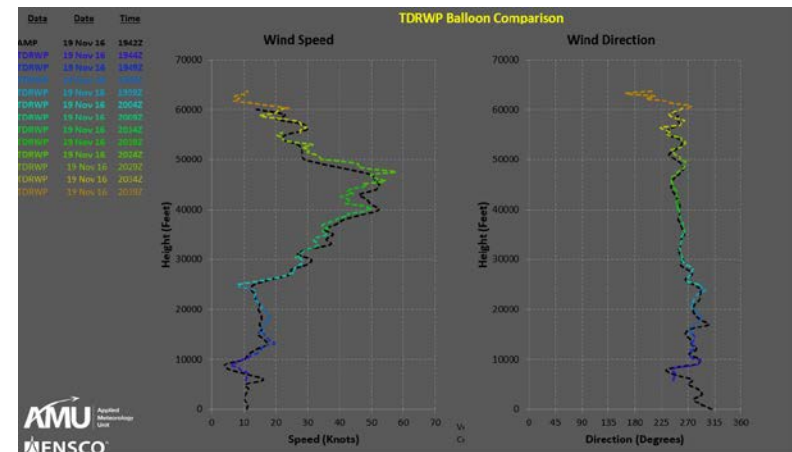
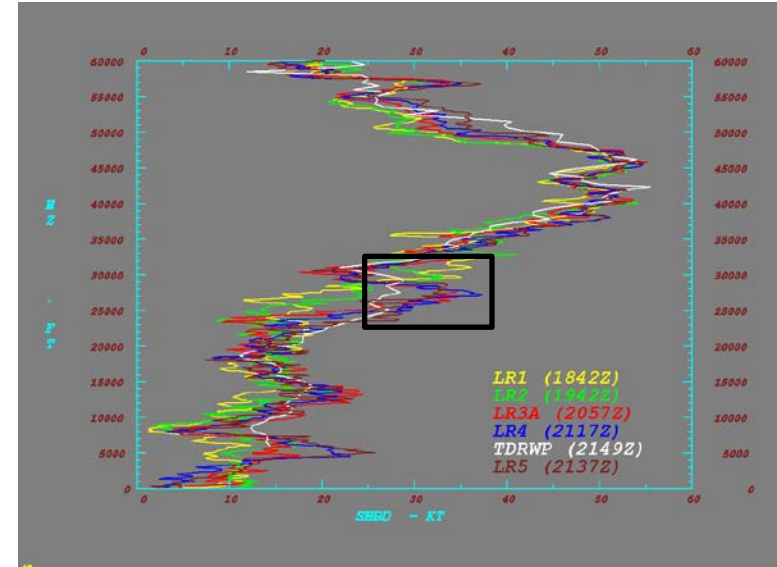
29 March 2017

*Presentation to the Natural Environments Day-of-Launch Working Group*

# Background

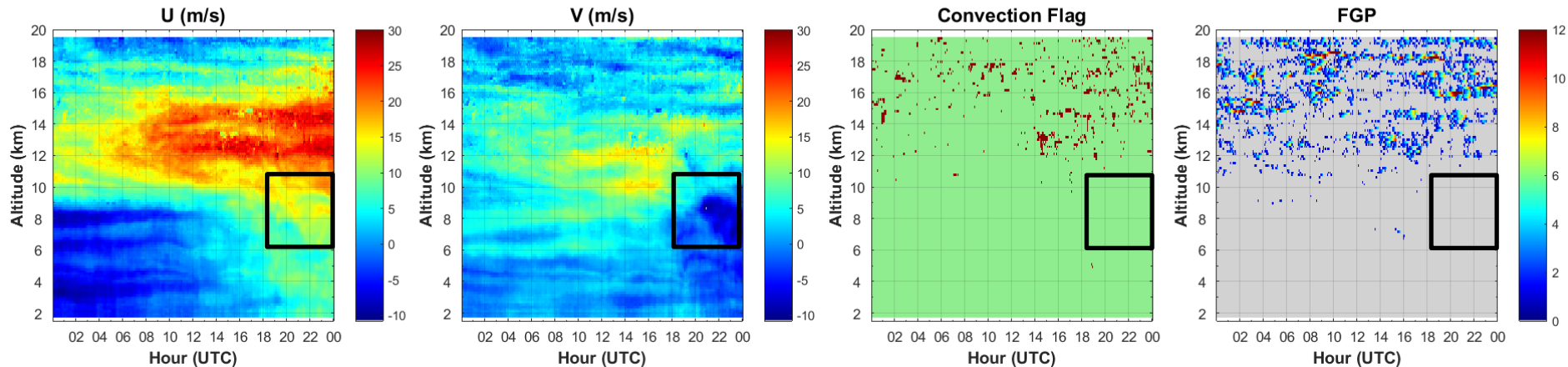
- Discrepancy in wind profiles noted during the launch countdown on 19 Nov 2016.
- Graphs showing data used during count.
  - Top: Wind speed profiles from multiple 100-ft LR releases and a single TDRWP measurement.
  - Bottom: Wind speed and direction profiles from a 1000-ft LR and a spliced TDRWP profile.
- LWO concerned that the TDRWP could have been underestimating wind speeds by as much as ~10 kt around 25-30 kft. Smaller discrepancy noted when using 1000-ft LR data.
- KSC Wx communicated discrepancy to MSFC NE, who performed the analysis contained in these charts.
  - TDRWP and LR comparisons done using OAT methodology and DOL philosophy.
  - Q1: Is the TDRWP reporting bad data?
  - Q2: Is the 100-ft LR better than the 1000-ft LR?

*Backup contains a list of acronyms*



# TDRWP Data for the Entire Day

11/19/2016 TDRWP Time-Height Plots



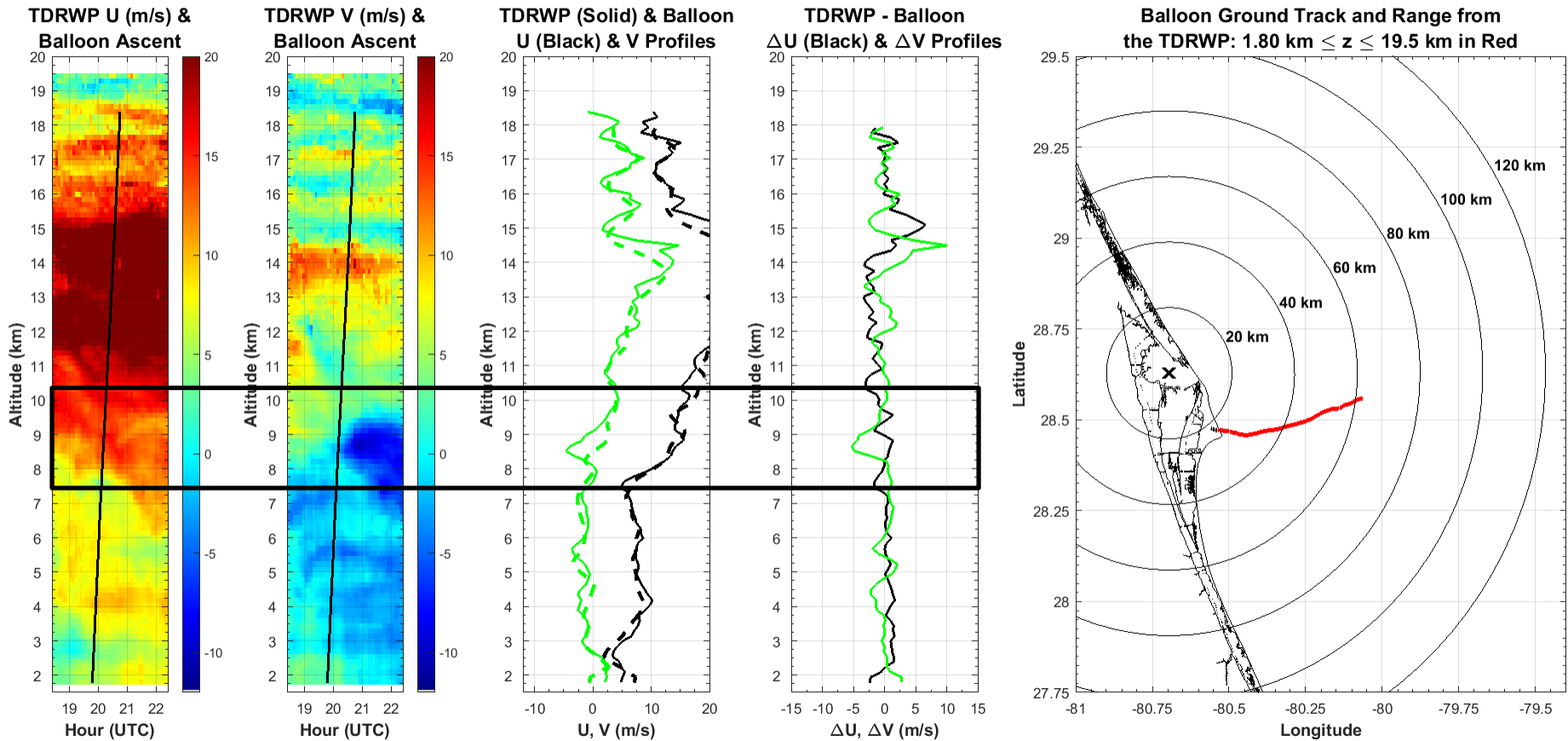
- TDRWP data are generally consistent throughout the day.
  - No convection noted
  - No evidence of measurement issues
  - Noted suspect data from ~14-21 UTC and ~12-15 km (39.4-49.2 kft). Possible weak signal, but not in the t-z region of interest, which is ~18-23 UTC and ~7.5-10.5 km (24.6-34.4 kft).
- Dynamic wind environment existed at the times and altitudes of interest
  - U increased from ~5-15 m/s (9.7-29.1 kts) across some time and altitude regimes.
  - V changed from ~0 m/s to -10 m/s (19.4 kts). Note larger negative V indicates an increase in northerly wind magnitude.

# Comparison #1: OAT Methodology

- Goal: Determine if the TDRWP was providing good data per comparison to vertically and temporally-consistent balloon measurements.
- Generated temporally and vertically matched TDRWP and balloon profiles.
  - Block-averaged all 1-s balloon data over a 150-m (492-ft) altitude interval centered on each TDRWP altitude.
  - Obtain TDRWP report at closest time to balloon report at each altitude.
- Plots
  - TDRWP wind component t-z sections with balloon ascent path overlaid.
  - Overlays of TDRWP and balloon wind component profiles.
  - Profiles of wind component deltas (TDRWP – balloon).
  - Balloon ground track.
- Summary
  - At 1942 UTC, the TDRWP wind components exceeded the balloon wind components by as much as 5 m/s (10 kt).
  - Balloons released later began to sample the environment that had already passed over the TDRWP, thus increasing the magnitude from the balloon profile.
  - Bottom line: The TDRWP was appropriately sampling the environment. Some differences are expected due to the balloon drifting downrange in a dynamic wind regime.

# OAT Comparison: 1942 UTC

## TDRWP and Balloon Comparison, Case 4: Balloon Release at 11/19/2016 19:42 UTC



# Comparison #2: DOL Application

- Each measurement system estimates the actual wind profiles with specified precision and noise characteristics.
  - Each profile consists of a combination of different features with different wavelengths.
  - Larger features persist with time and smaller features are more transient.
- MSFC NE approach removes the necessity to depend on a single wind profiling system on DOL
  - Upload steering commands to the vehicle using a non-persistent wind profile a few hours before launch.
  - Assess whether or not the vehicle can fly through the (unknown) launch wind using previously-derived KDs on various indicators.
    - KD derived as a function of wavelength content, which is related to time before launch.
    - Trajectory assessments that implement these KDs account for features with wavelengths at least those measureable by given systems.
    - Separate “gust” analyses account for wavelengths smaller than what systems can measure.
  - Only systems that measure atmospheric features with wavelengths greater than those accounted for by the “gust” analysis are needed.

# Comparison #2: DOL Application

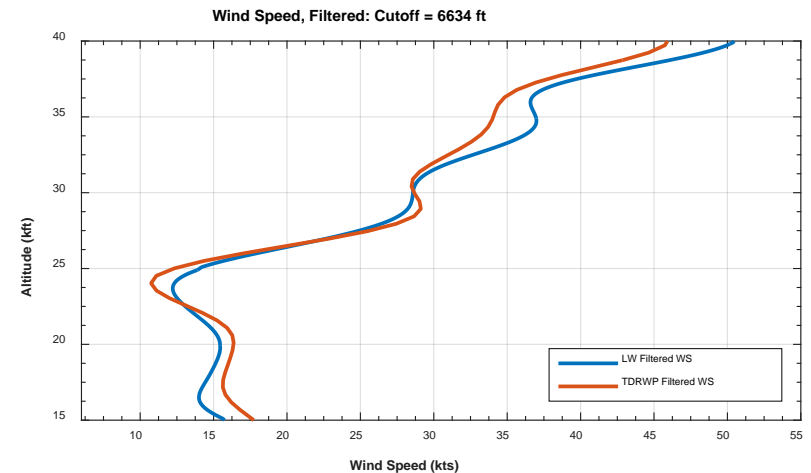
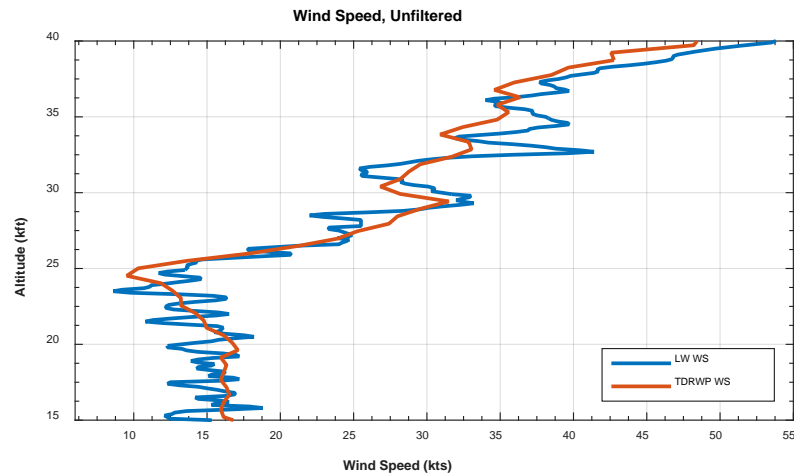
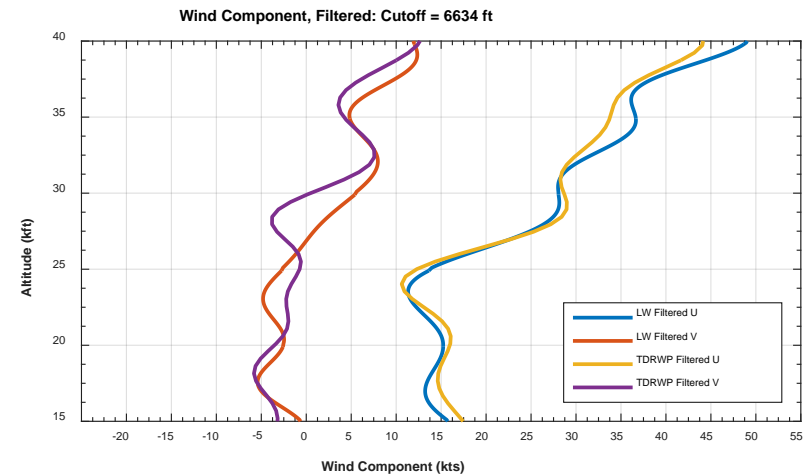
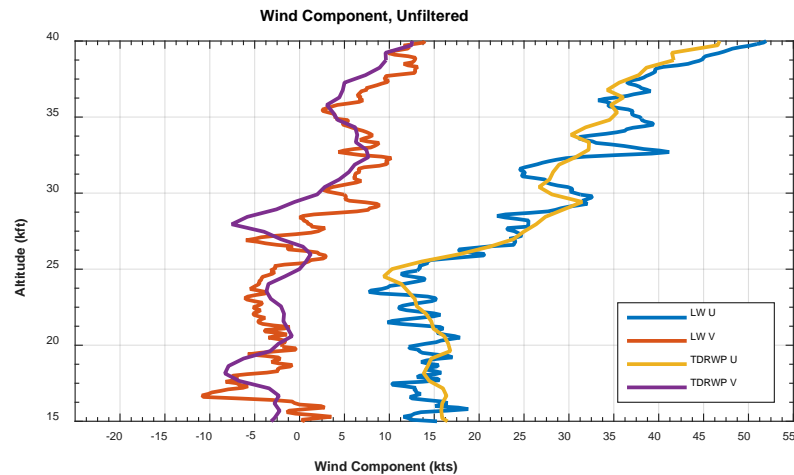
- Launch time: 2342 UTC
- Examined LW\* and TDRWP profiles separated by 30 minutes.
- Applied a low-pass filter to both profiles with the cutoff wavelength varying as a function of time before launch [ $WL = 460 * \sqrt{T}$ ].

Balloon Release (UTC)	TDRWP Profile (UTC)	Time Before Launch (min)	Cutoff Wavelength (ft)
1842	1914	268	7531
1942	2014	208	6634
2057	2129	133	5305
2137	2209	93	4436

- Overlaid unfiltered wind components and wind speed.
- Plots display the reduction in differences between the two systems upon implementing the filter. This effect has less effect later in the countdown.
- Again, differences attributed to wind regime changes within the balloon's spatial separation.

# Single Profile Comparison: 1942 UTC

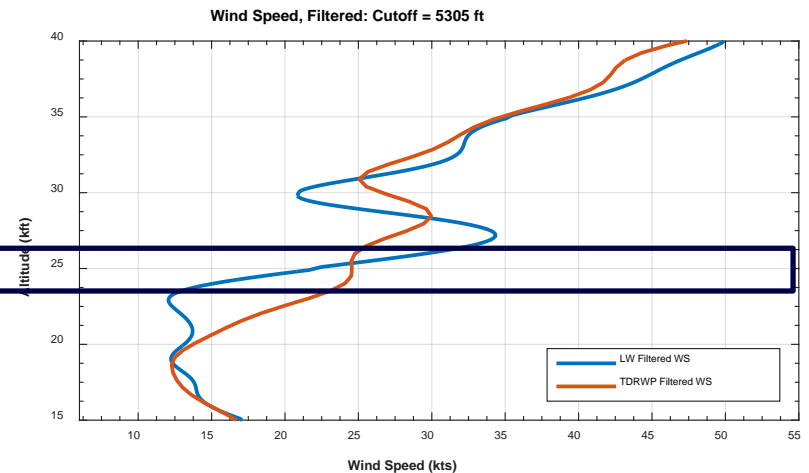
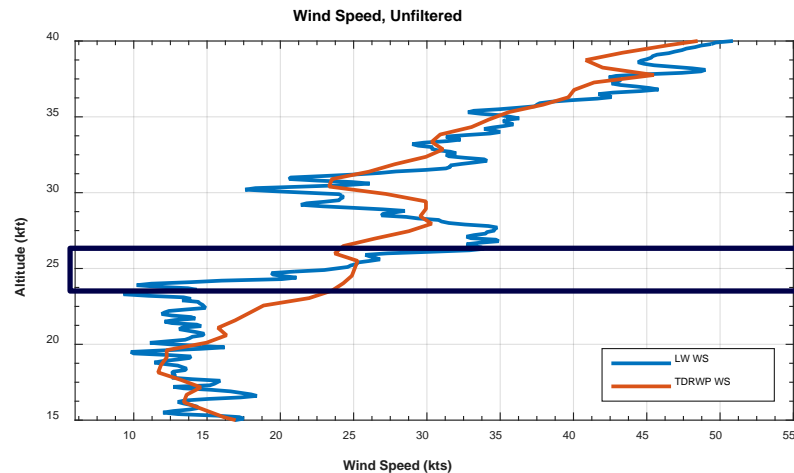
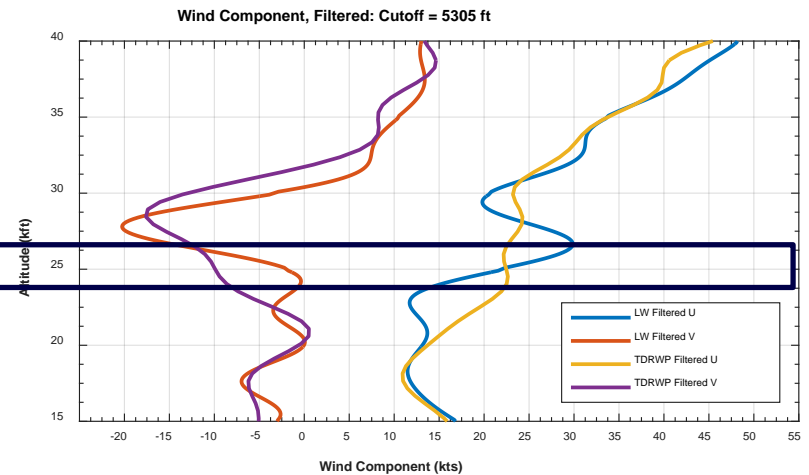
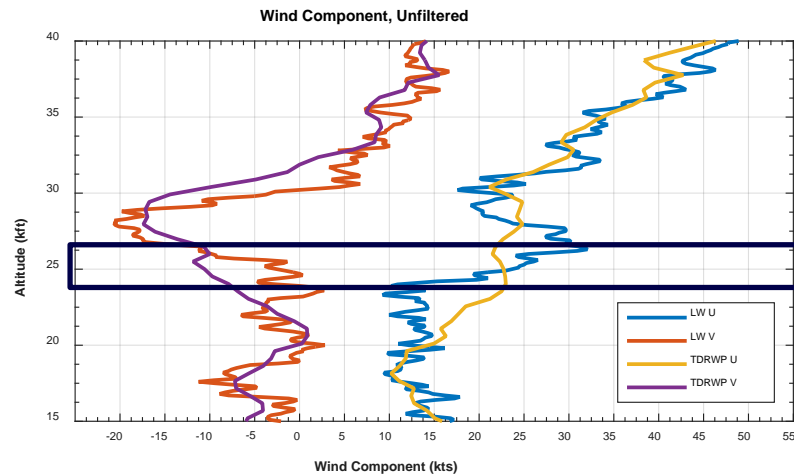
Comparison Between LW at 11/19/2016 1942 UTC and TDRWP at 11/19/2016 2014 UTC





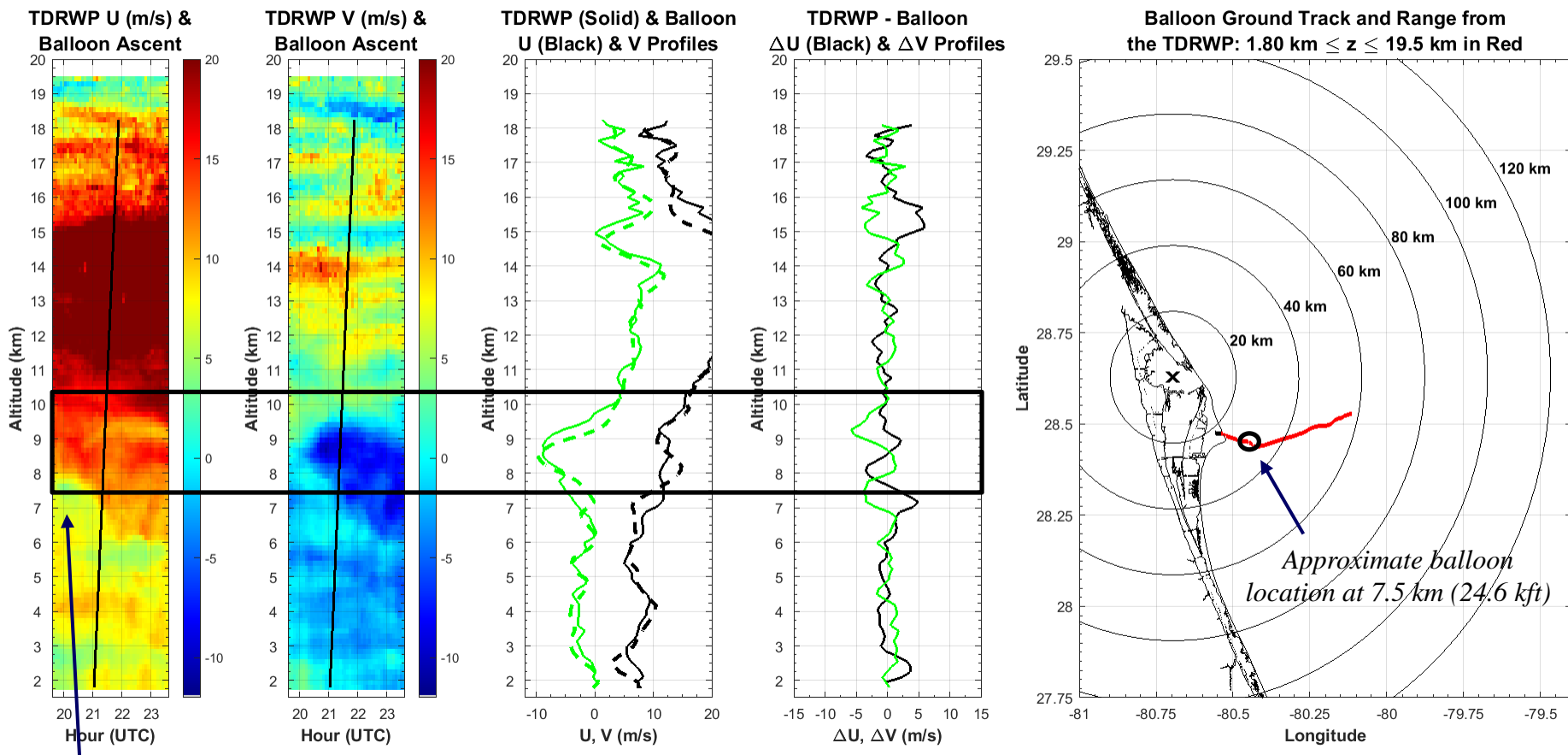
# Single Profile Comparison: 2057 UTC

Comparison Between LW at 11/19/2016 2057 UTC and TDRWP at 11/19/2016 2129 UTC



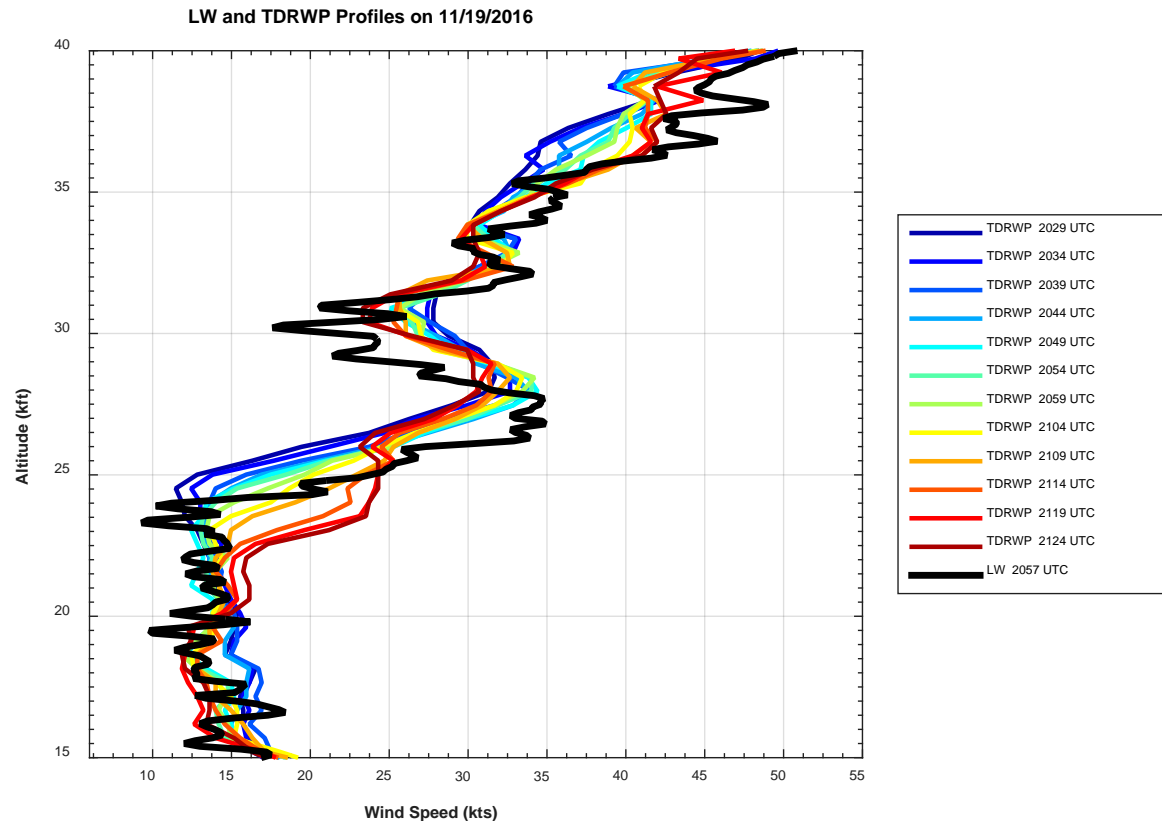
# OAT Comparison: 2057 UTC

## TDRWP and Balloon Comparison, Case 5: Balloon Release at 11/19/2016 20:57 UTC



*Shear from ~7.5-8.0 km (24.6-26.2 kft) was over the DRWP until ~2100 UTC*

# Multiple Profile Comparison: 2057 UTC



- Graph shows unfiltered TDRWP profiles within ½ hour of the 2057 UTC LW profile.
- Enhanced shear noted in TDRWP profiles from ~2044-2104 UTC. Subsequent TDRWP profiles do not measure the enhanced shear.
- Remaining differences attributed to spatial separation.

# Summary

- MSFC NE examined TDRWP and balloon profiles measured during the GOES-R launch on 19 Nov 2016 in response to concerns that the TDRWP was underestimating the maximum wind speed around 25-35 kft.
- Found that the TDRWP was adequately measuring the environment.
- Differences are attributed to balloon spatial separation in a dynamic wind environment, and directly comparing systems with different vertical resolutions.
- Accounting for these measurement differences reduces the differences seen in profiles from the two systems.
- Charts show how only examining persistent wavelength content, tied to how vehicle programs apply DOL winds, could mitigate the concerns brought forth.

## Backup

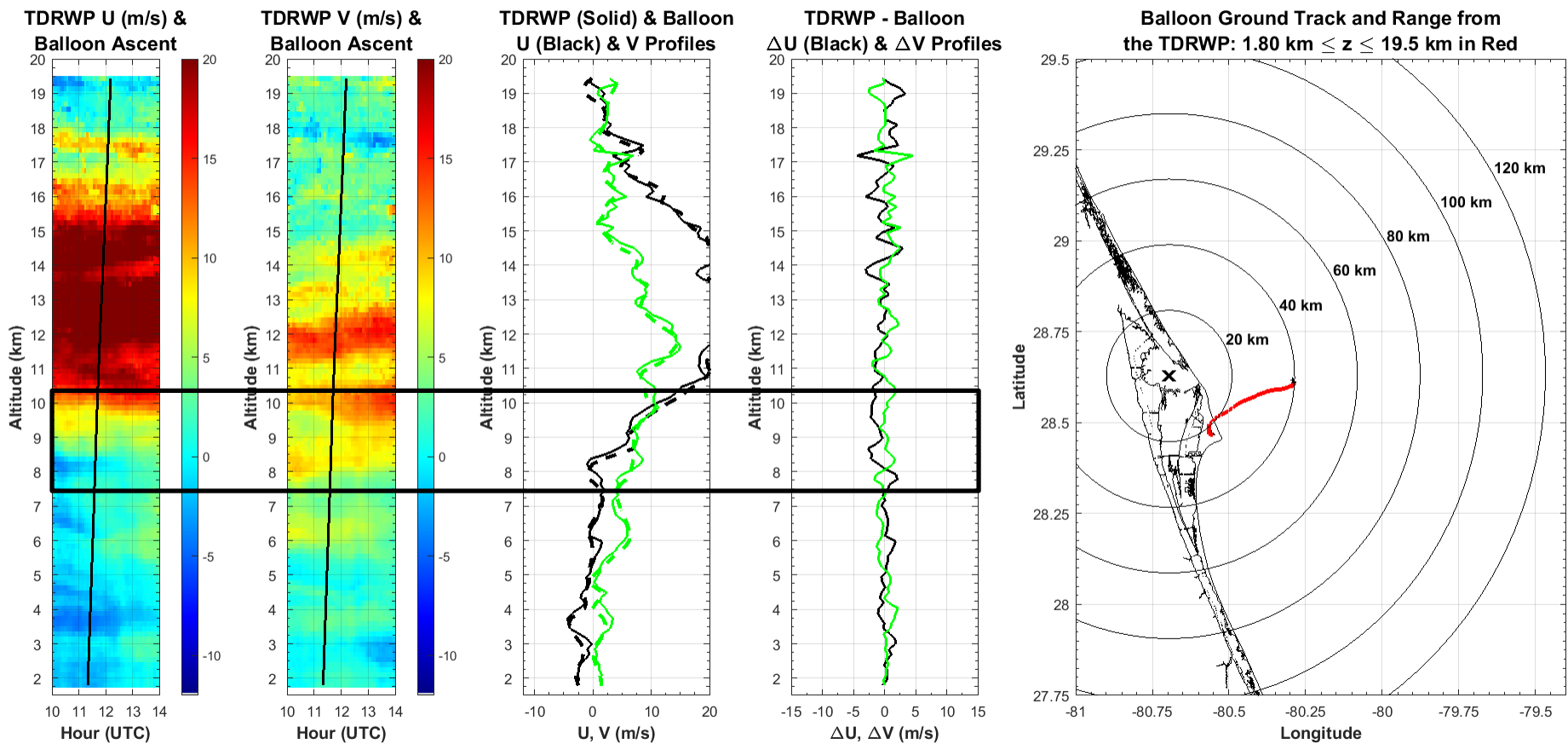
- List of Acronyms
- All 11 OAT Comparisons
- All four Single Profile Comparisons
- 2057 UTC filtered TDRWP and LW profiles

# List of Acronyms

AMU	Applied Meteorology Unit
DOL	day-of-launch
ft	feet
GOES-R	Geostationary Operational Environmental Satellite-R series
KD	knockdown
kft	kilofeet
km	kilometers
KSC Wx	Kennedy Space Center Weather
kt	knots
LR	Low-Resolution Flight Element
LW	Low-Resolution Flight Element - winds only file
LWO	Launch Weather Officer
m	meters
m/s	meters per second
MSFC NE	Marshall Space Flight Center Natural Environments Branch
OAT	Operational Acceptance Test
Qn	Question n
s	second
TDRWP	Tropospheric Doppler Radar Wind Profiler
t-z	time-height
U	westerly wind component
UTC	Coordinated Universal Time
V	southerly wind component
$\Delta$	difference

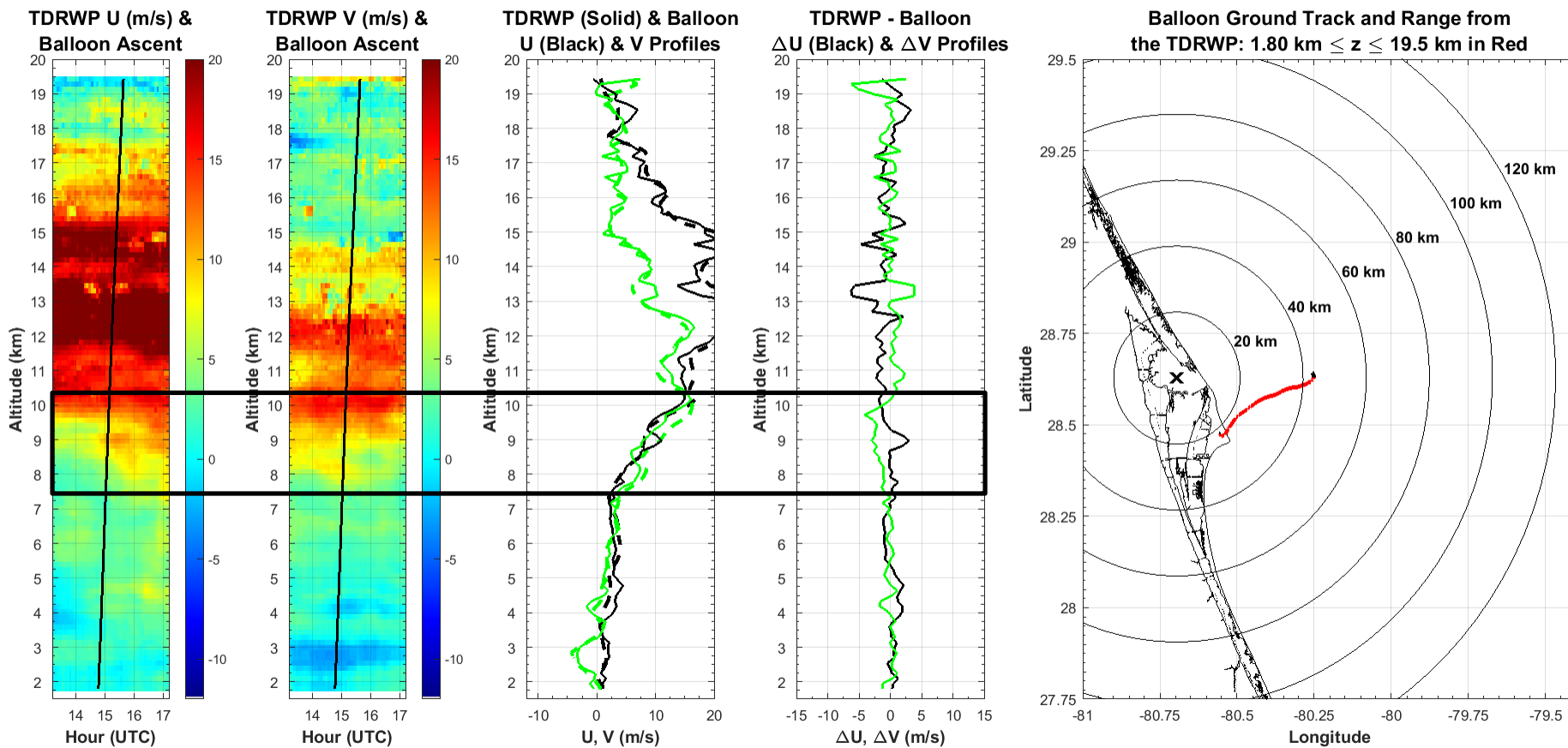
# OAT Comparison: 1115 UTC

## TDRWP and Balloon Comparison, Case 1: Balloon Release at 11/19/2016 11:15 UTC



# OAT Comparison: 1442 UTC

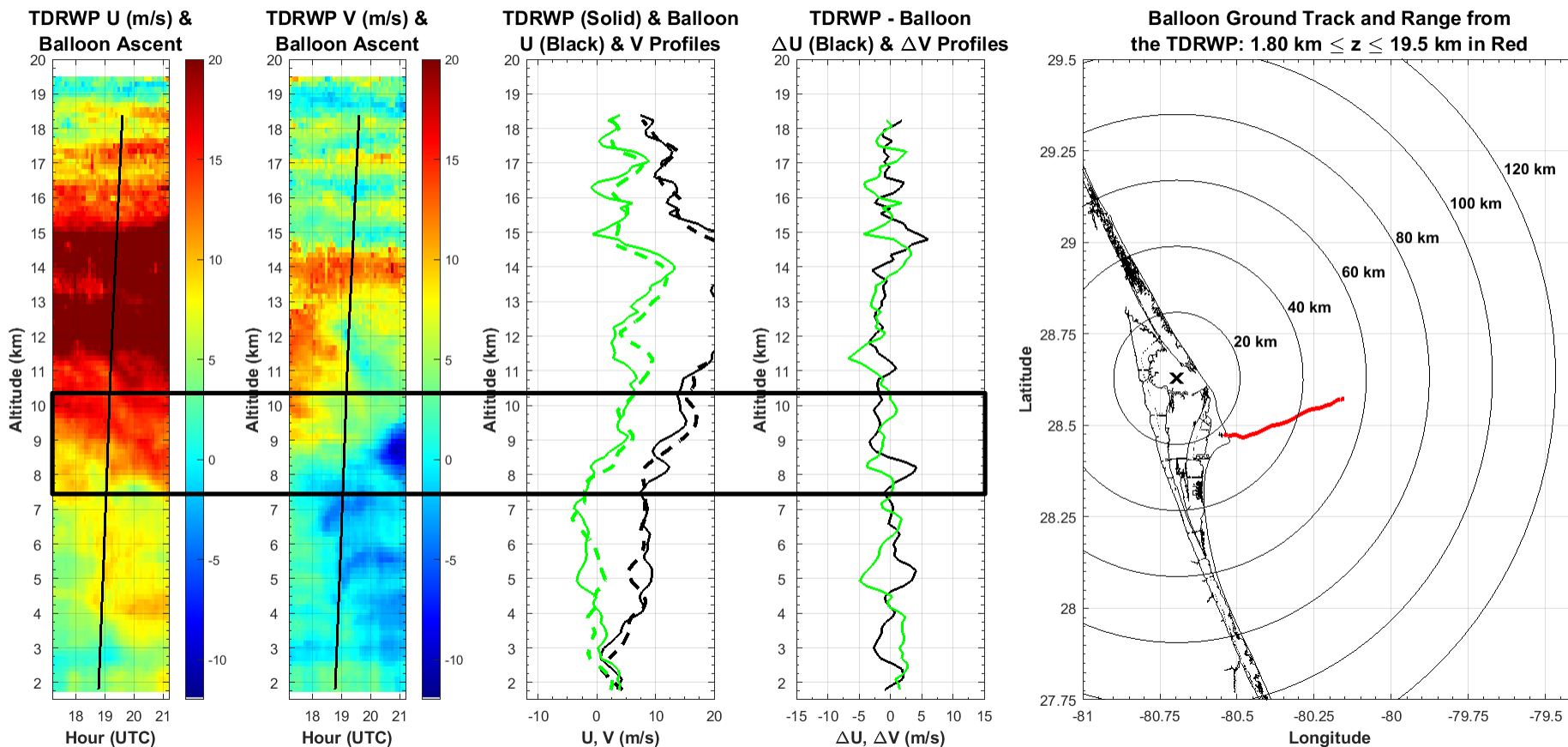
## TDRWP and Balloon Comparison, Case 2: Balloon Release at 11/19/2016 14:42 UTC





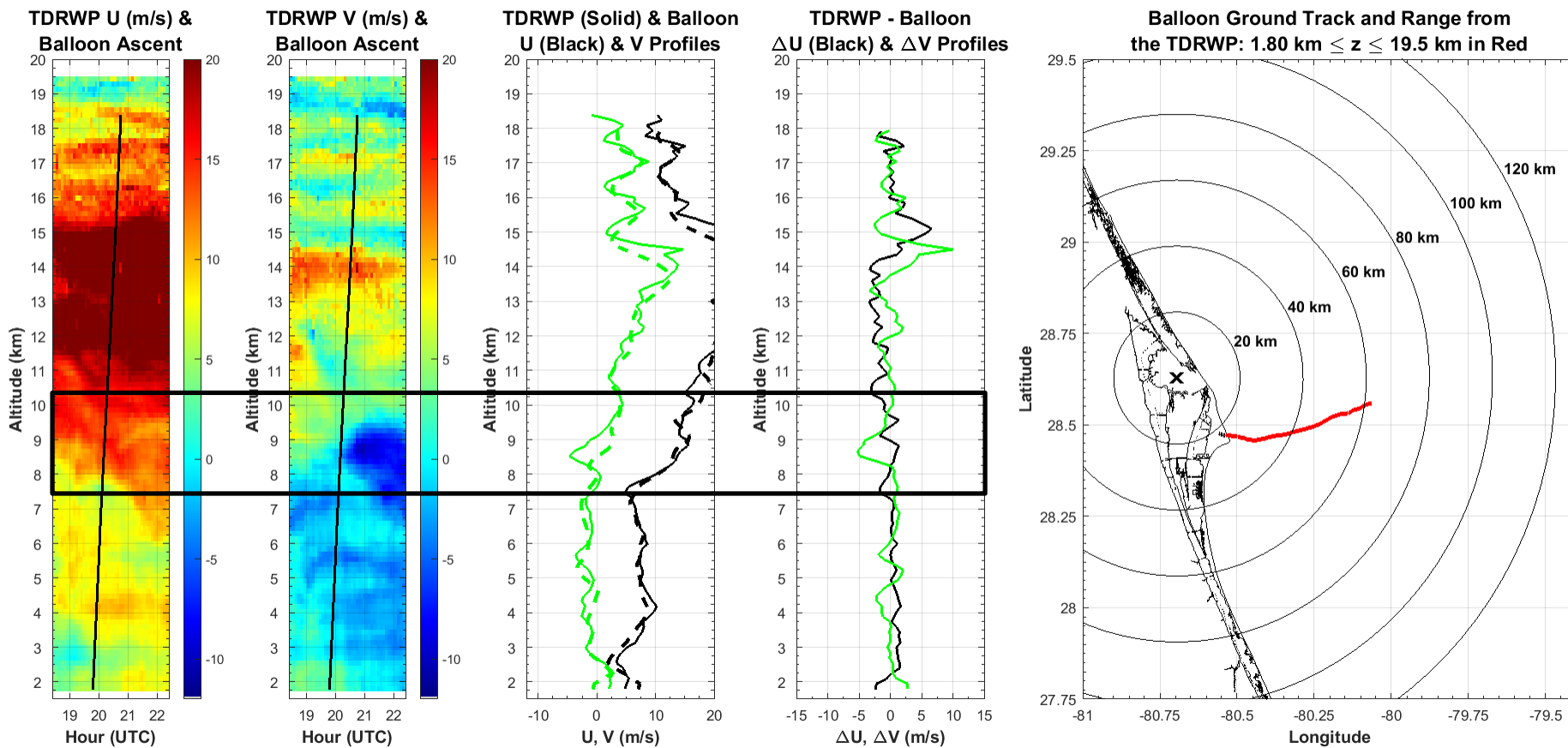
# OAT Comparison: 1842UTC

## TDRWP and Balloon Comparison, Case 3: Balloon Release at 11/19/2016 18:42 UTC



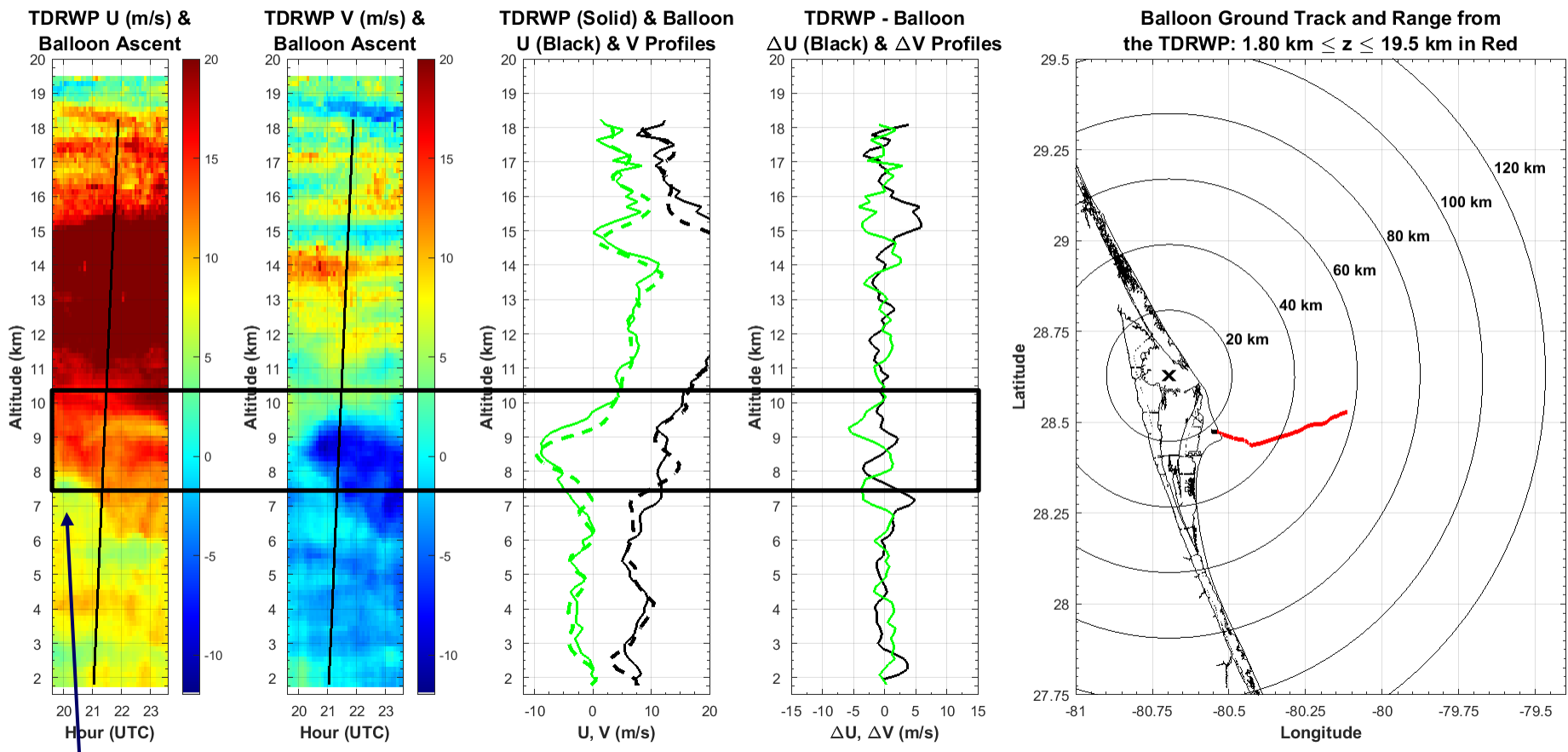
# OAT Comparison: 1942 UTC

## TDRWP and Balloon Comparison, Case 4: Balloon Release at 11/19/2016 19:42 UTC



# OAT Comparison: 2057 UTC

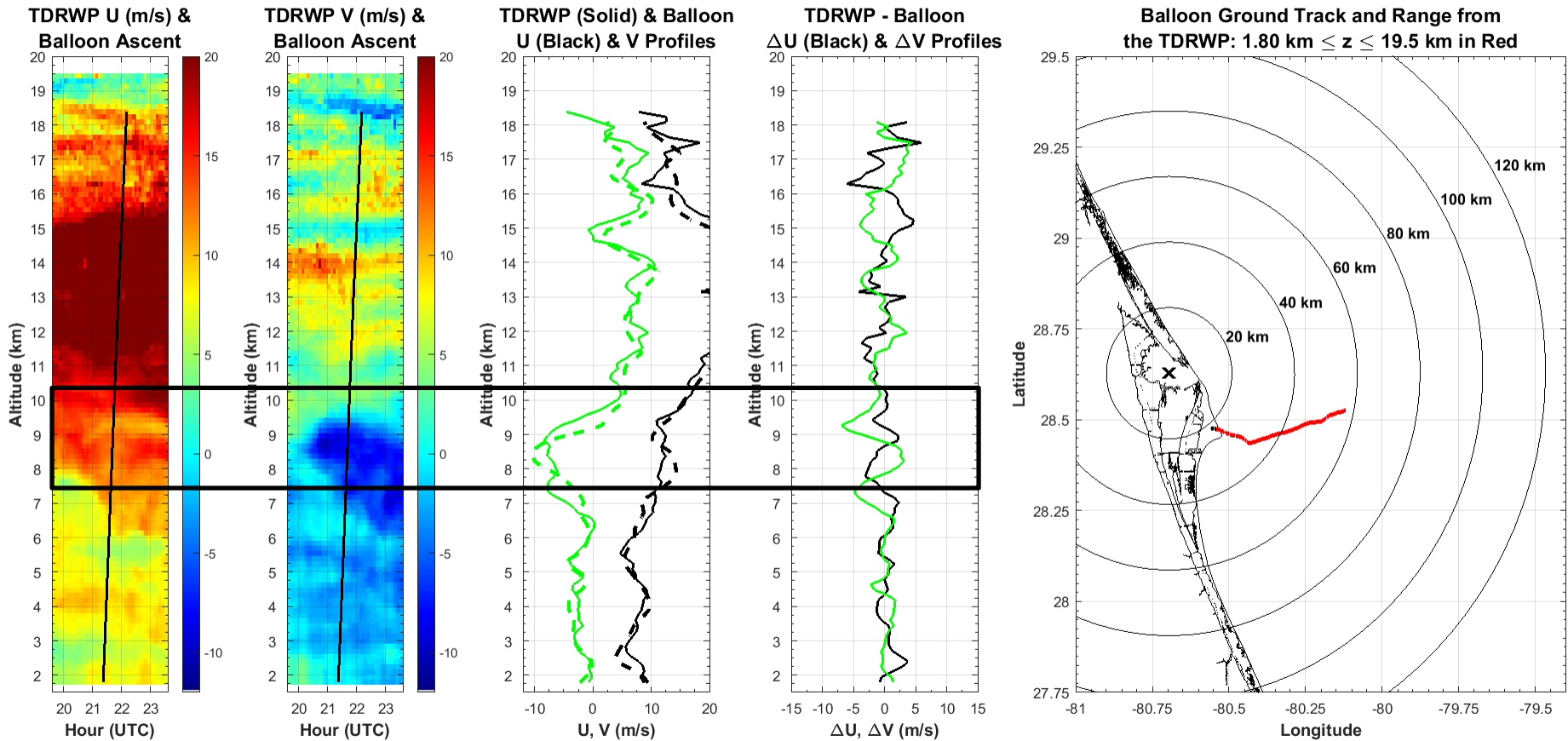
## TDRWP and Balloon Comparison, Case 5: Balloon Release at 11/19/2016 20:57 UTC



Note that enhanced shear from ~7.5-8.0 km (24.6-26.2 kft) exists until ~2100 UTC...

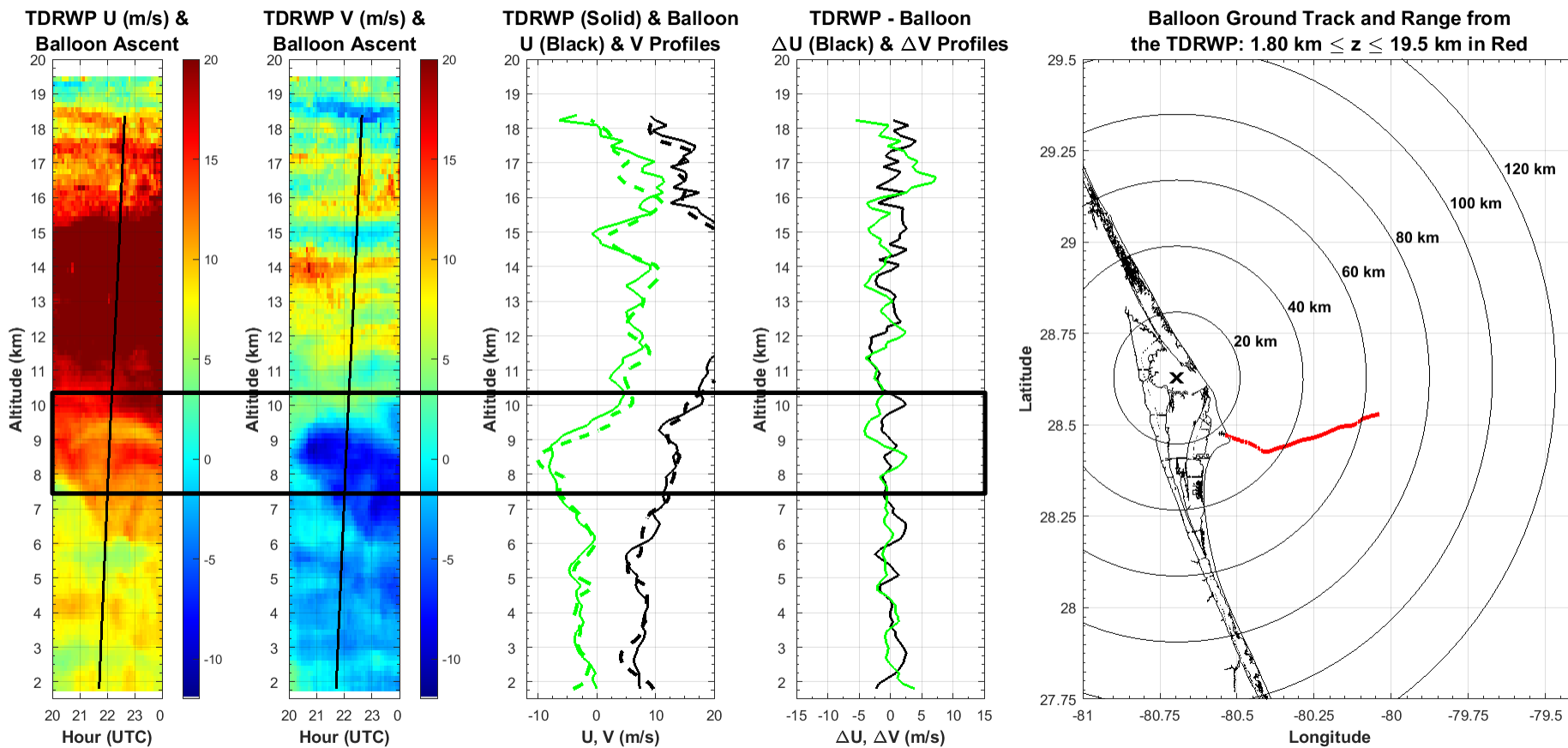
# OAT Comparison: 2117 UTC

## TDRWP and Balloon Comparison, Case 6: Balloon Release at 11/19/2016 21:17 UTC



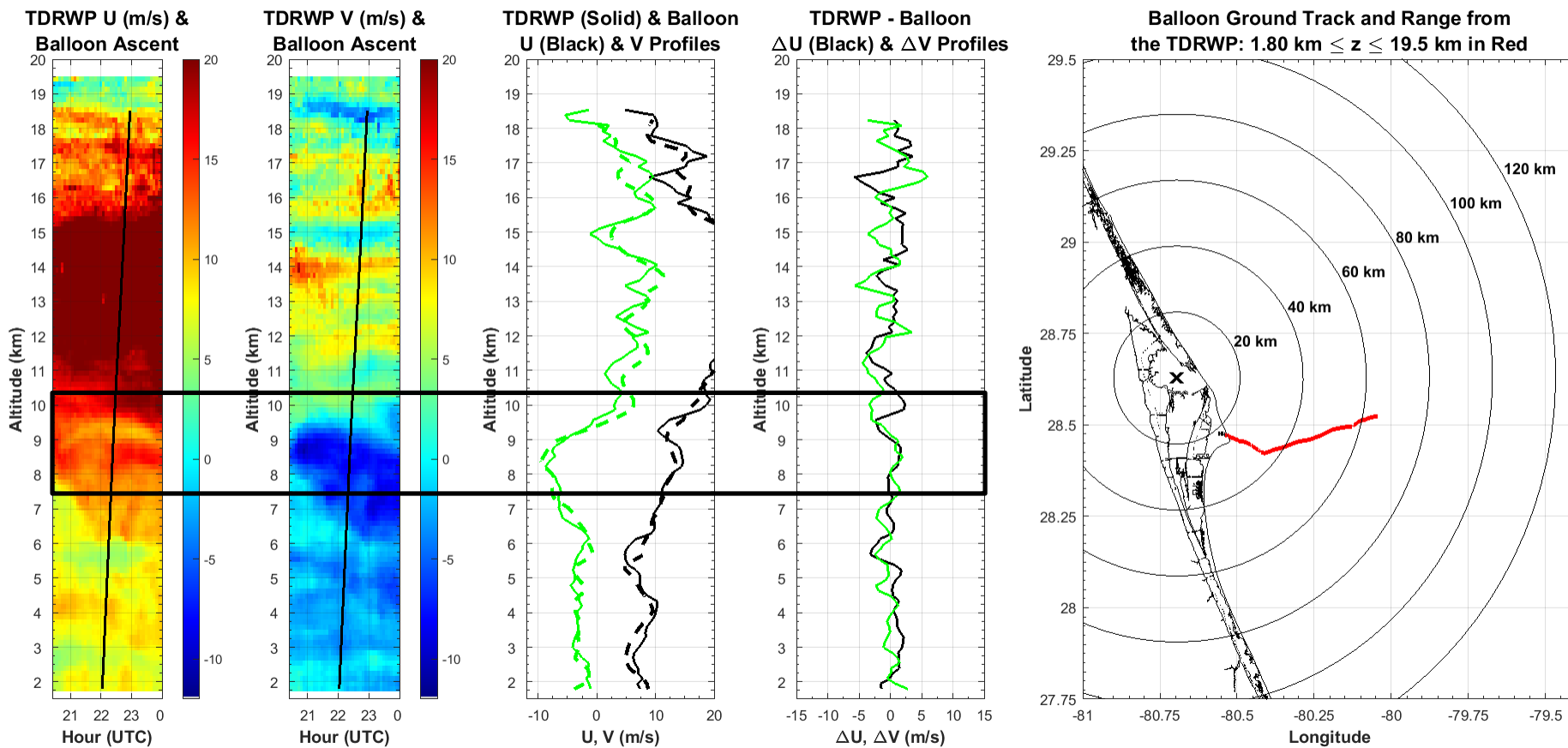
# OAT Comparison: 2137 UTC

## TDRWP and Balloon Comparison, Case 7: Balloon Release at 11/19/2016 21:37 UTC



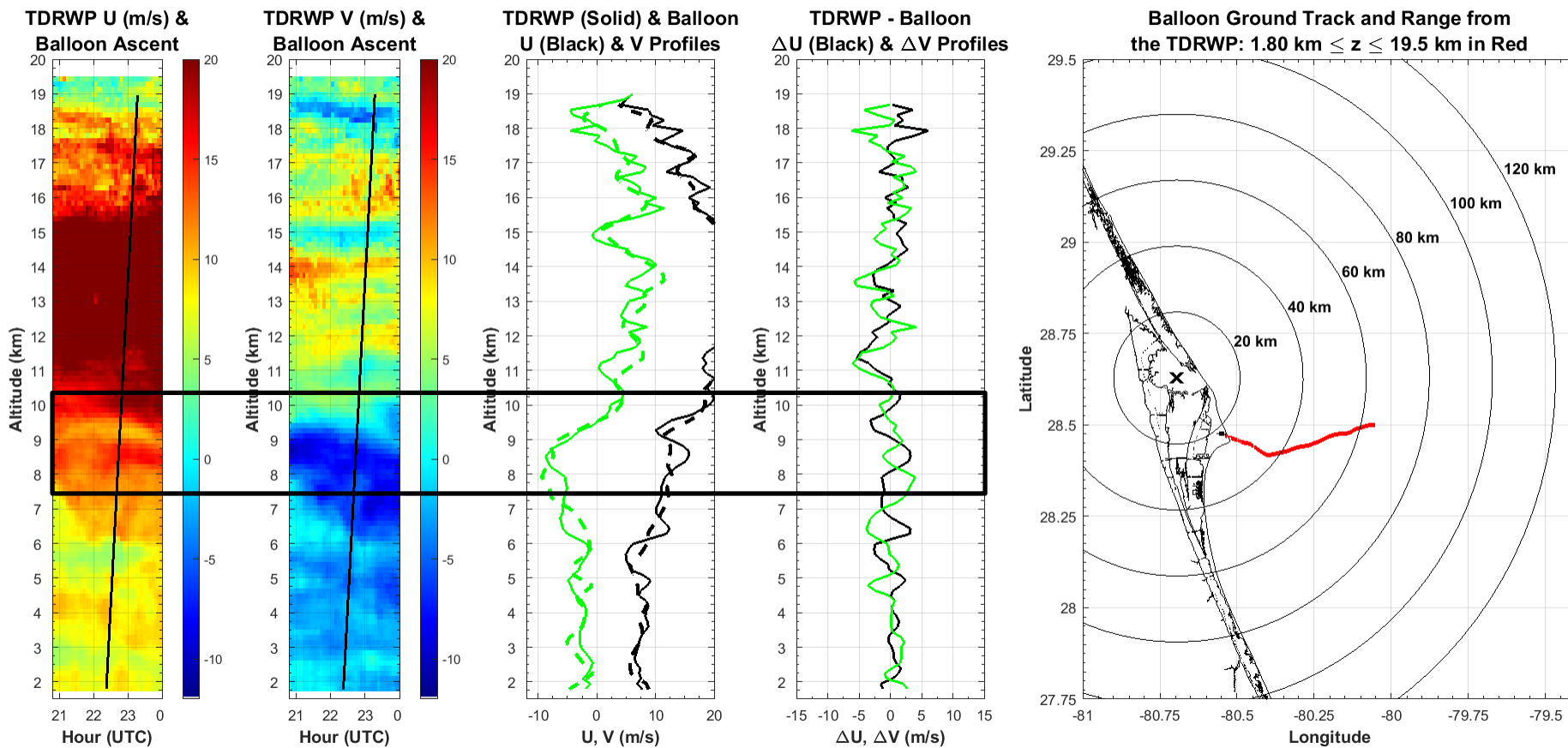
# OAT Comparison: 2157 UTC

## TDRWP and Balloon Comparison, Case 8: Balloon Release at 11/19/2016 21:57 UTC



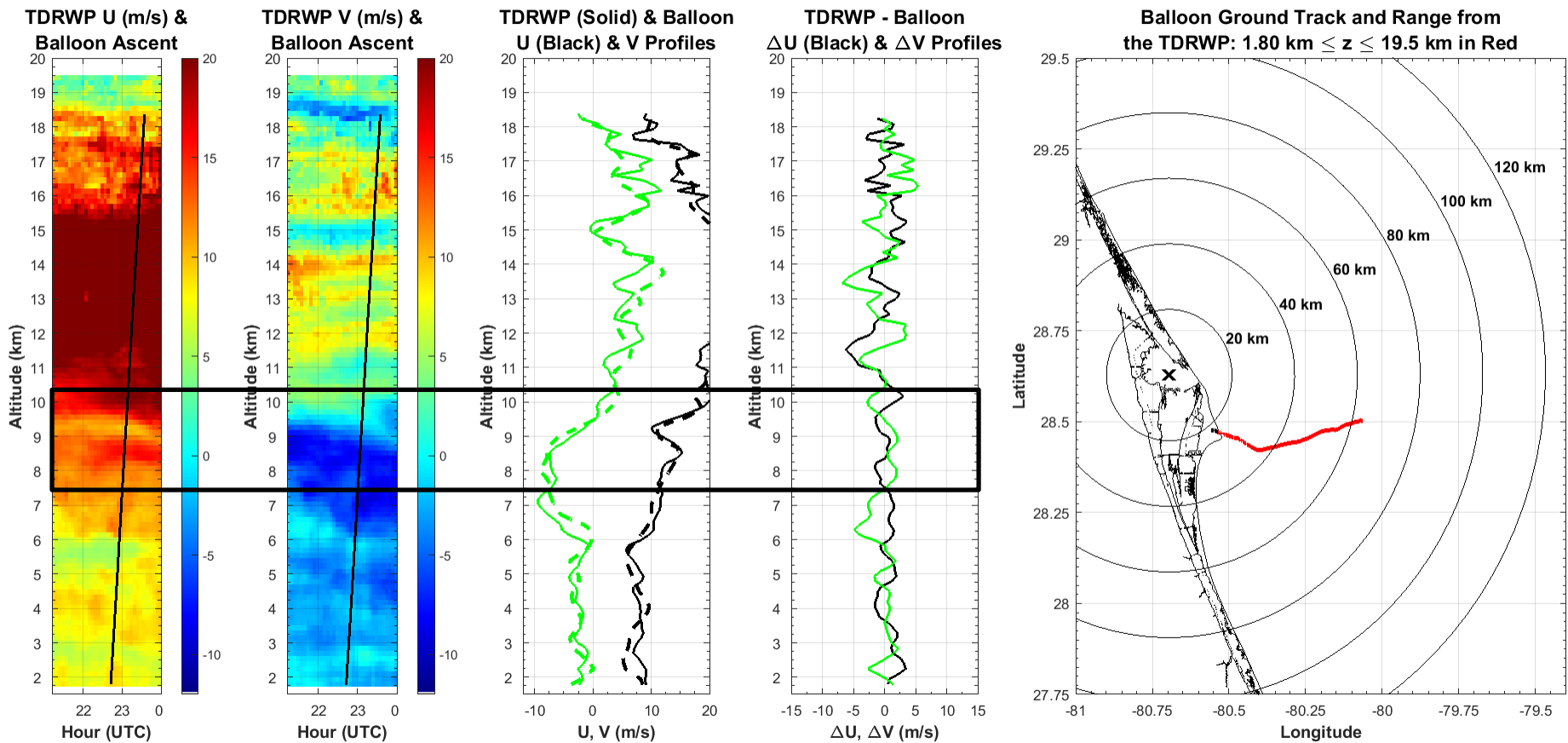
# OAT Comparison: 2217 UTC

## TDRWP and Balloon Comparison, Case 9: Balloon Release at 11/19/2016 22:17 UTC



# OAT Comparison: 2237 UTC

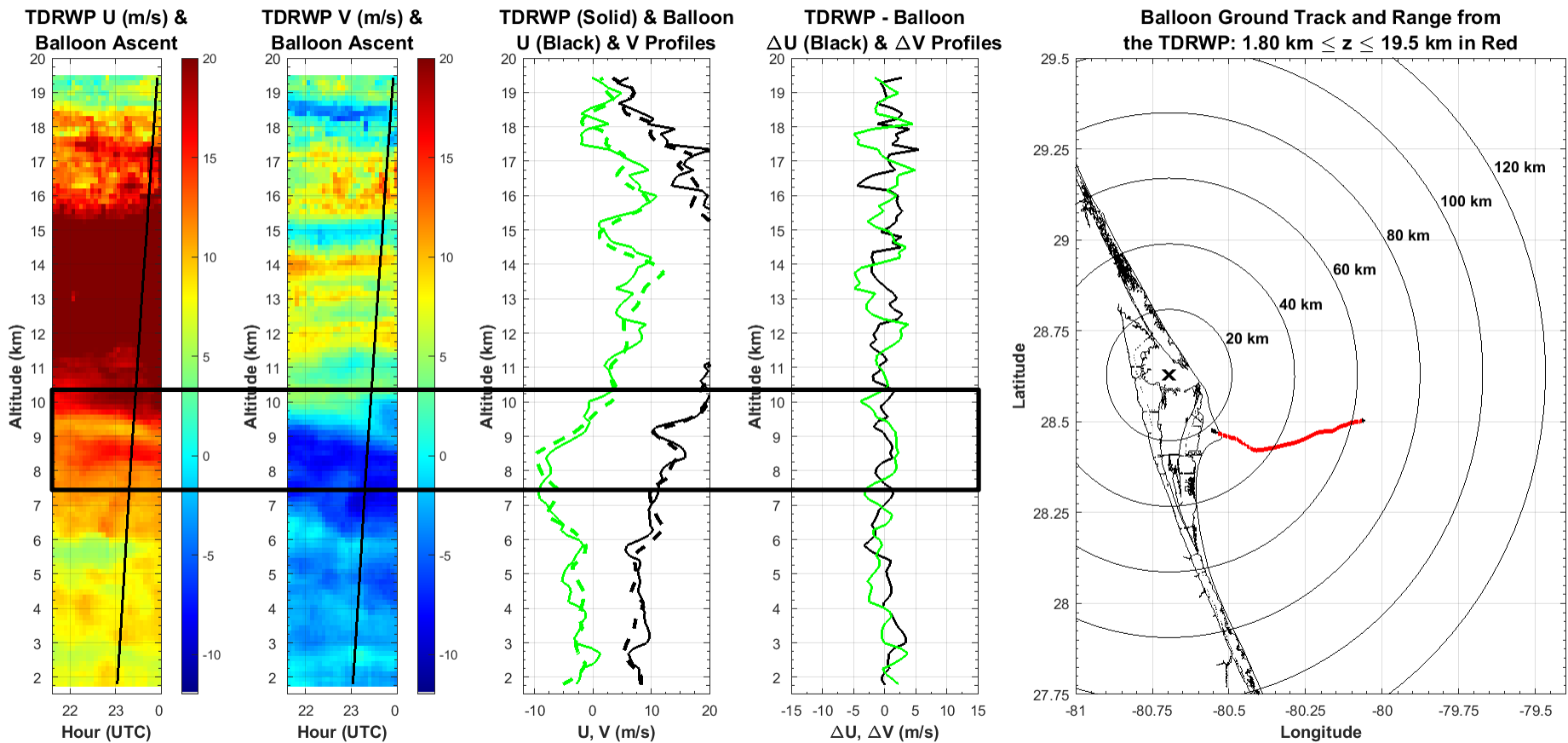
TDRWP and Balloon Comparison, Case 10: Balloon Release at 11/19/2016 22:37 UTC





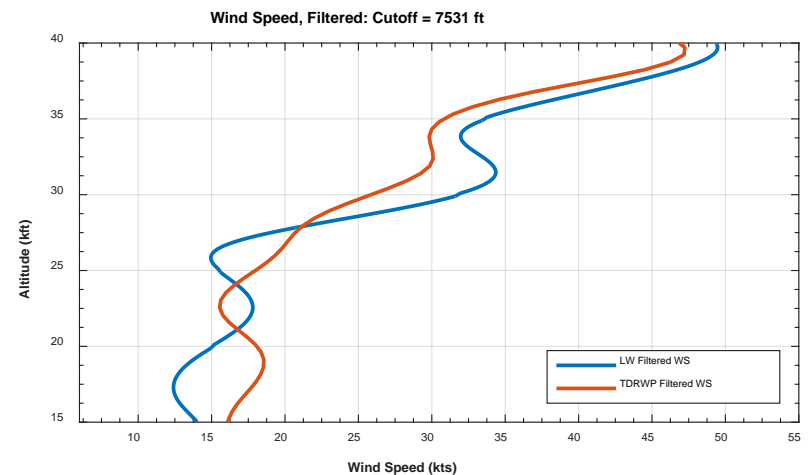
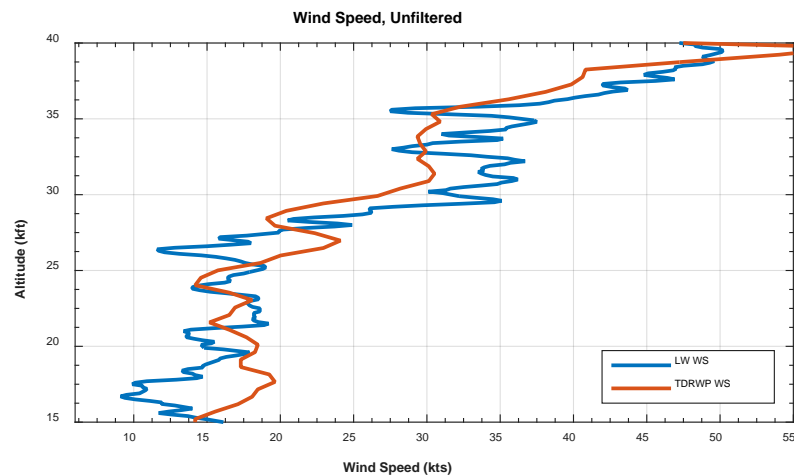
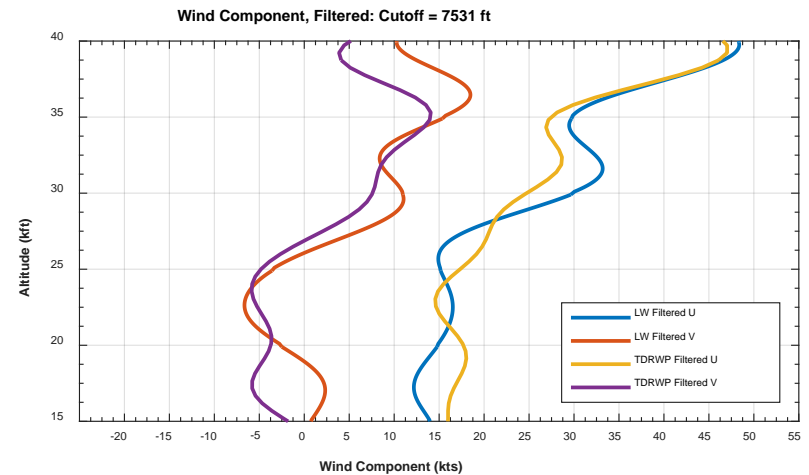
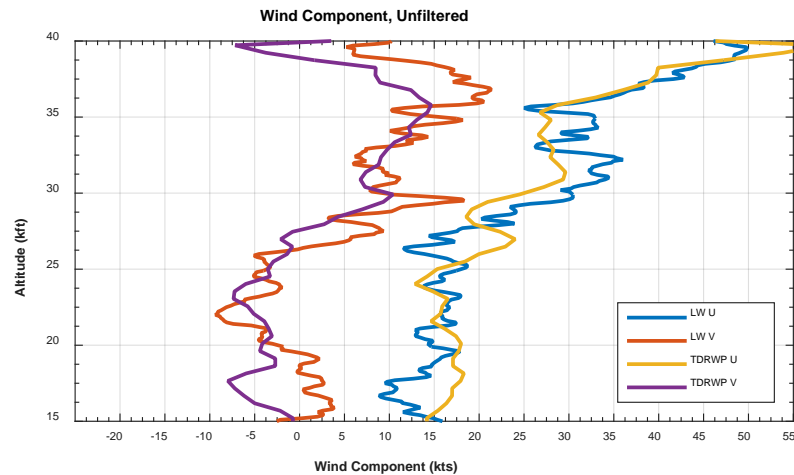
# OAT Comparison: 2257 UTC

TDRWP and Balloon Comparison, Case 11: Balloon Release at 11/19/2016 22:57 UTC



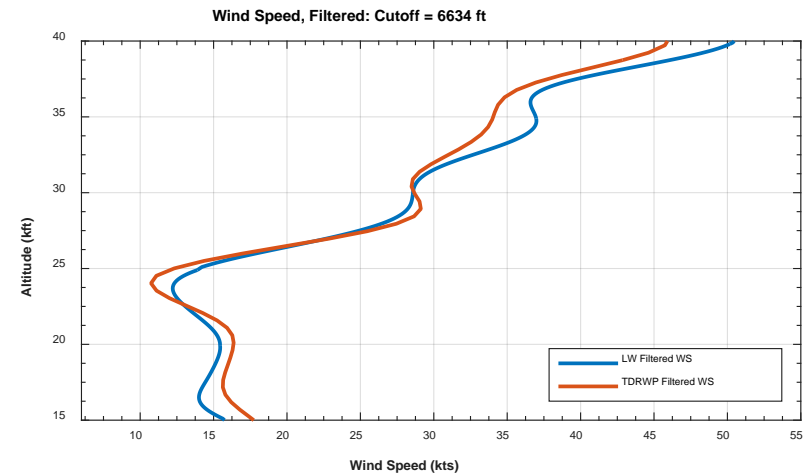
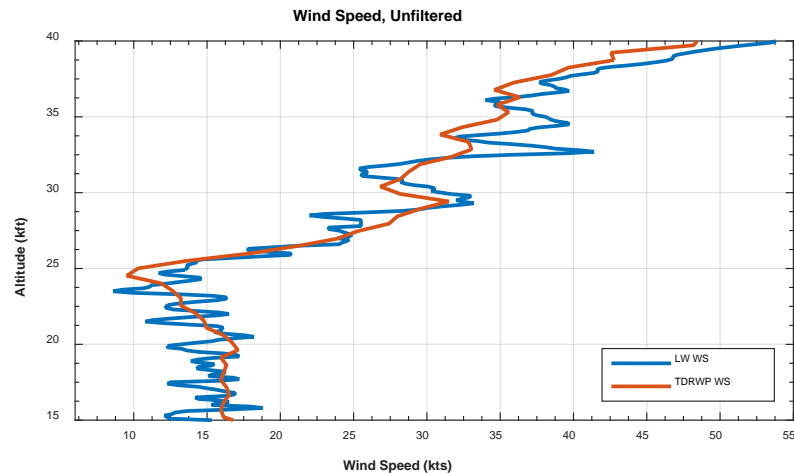
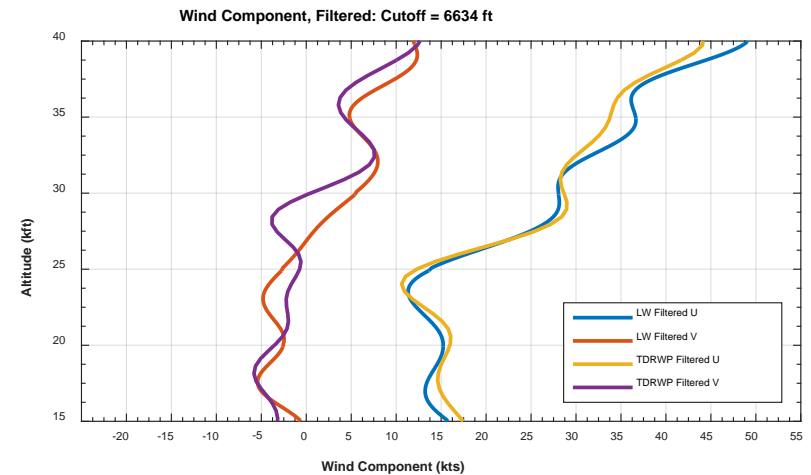
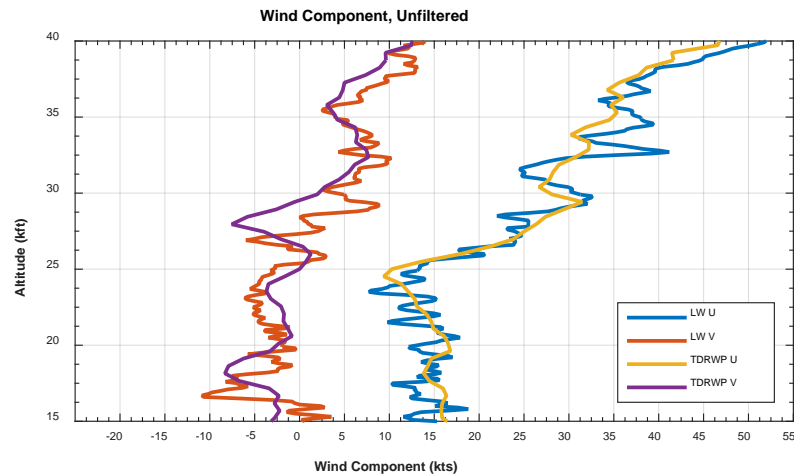
# Single Profile Comparison: 1842 UTC

Comparison Between LW at 11/19/2016 1842 UTC and TDRWP at 11/19/2016 1914 UTC



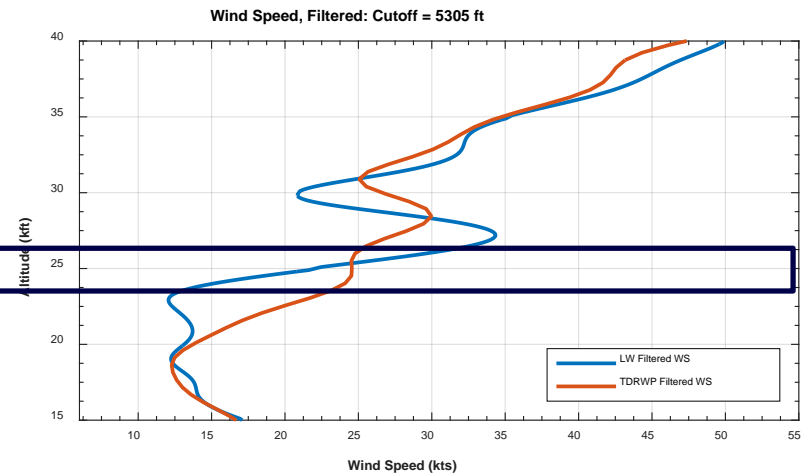
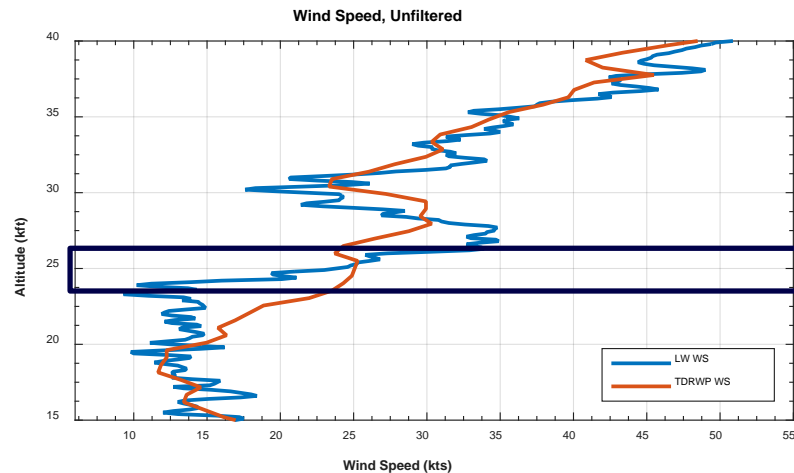
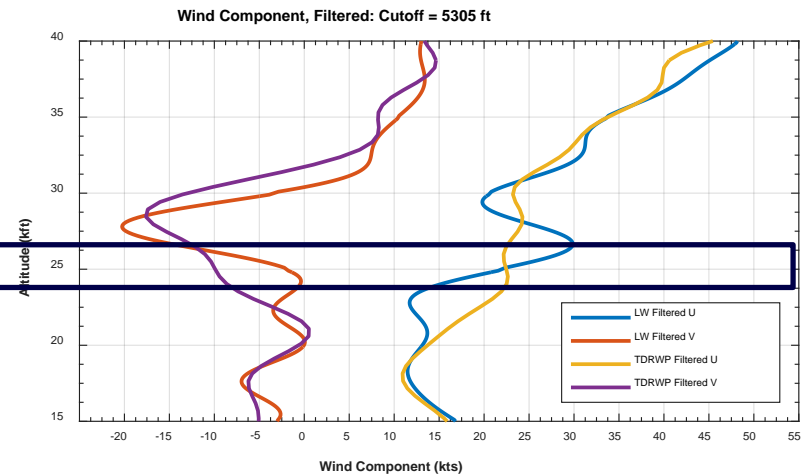
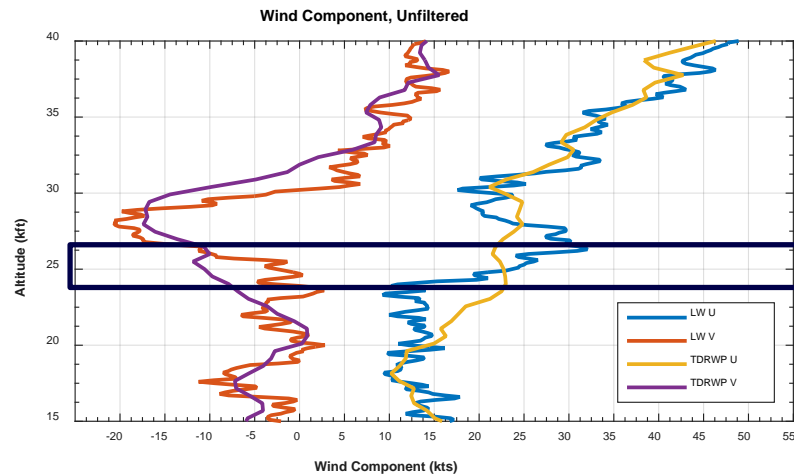
# Single Profile Comparison: 1942 UTC

Comparison Between LW at 11/19/2016 1942 UTC and TDRWP at 11/19/2016 2014 UTC



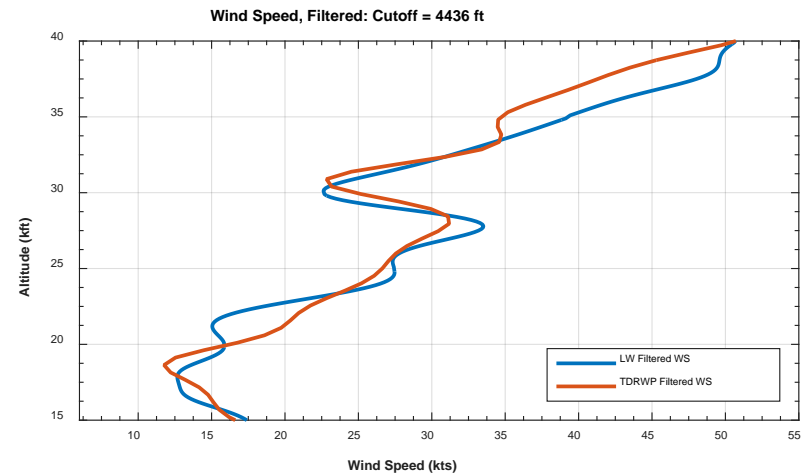
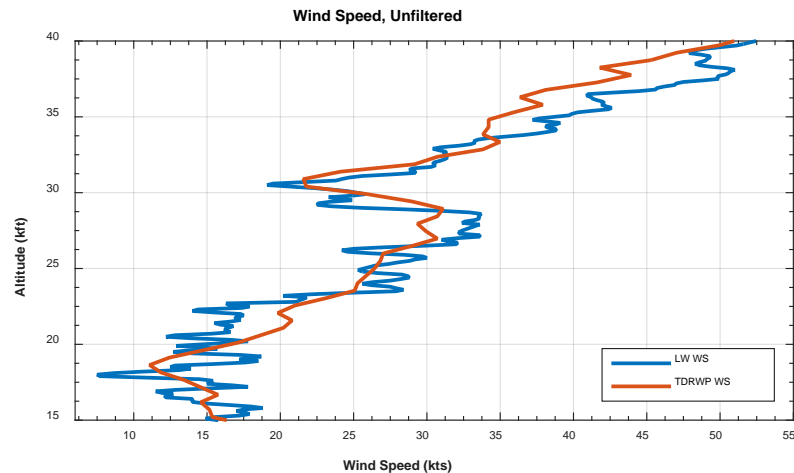
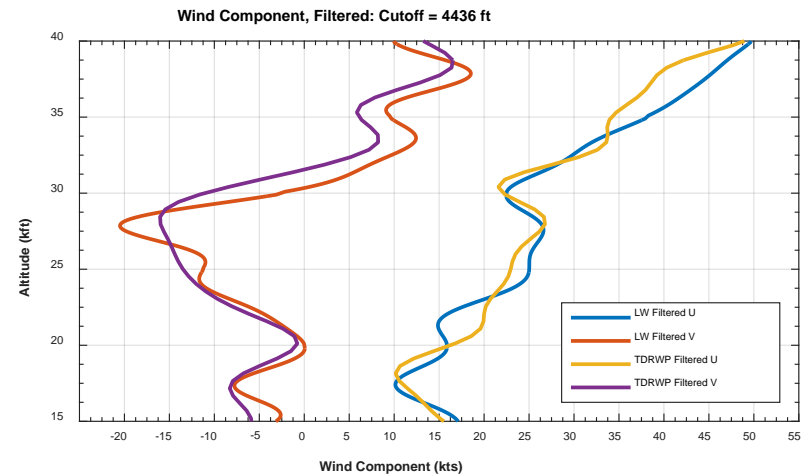
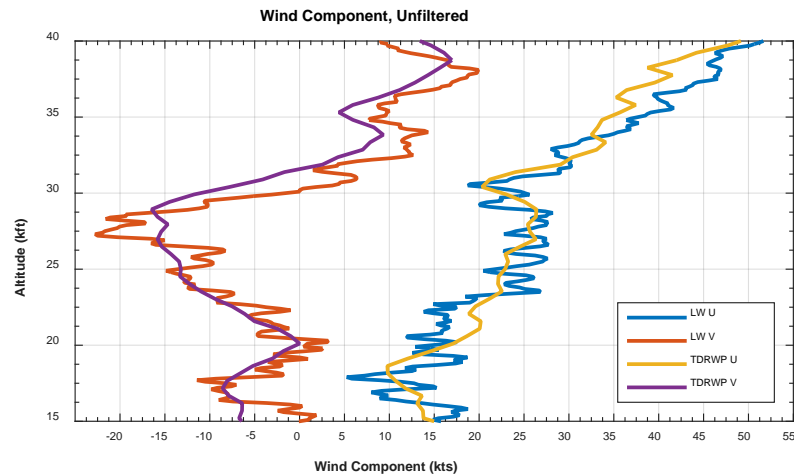
# Single Profile Comparison: 2057 UTC

Comparison Between LW at 11/19/2016 2057 UTC and TDRWP at 11/19/2016 2129 UTC

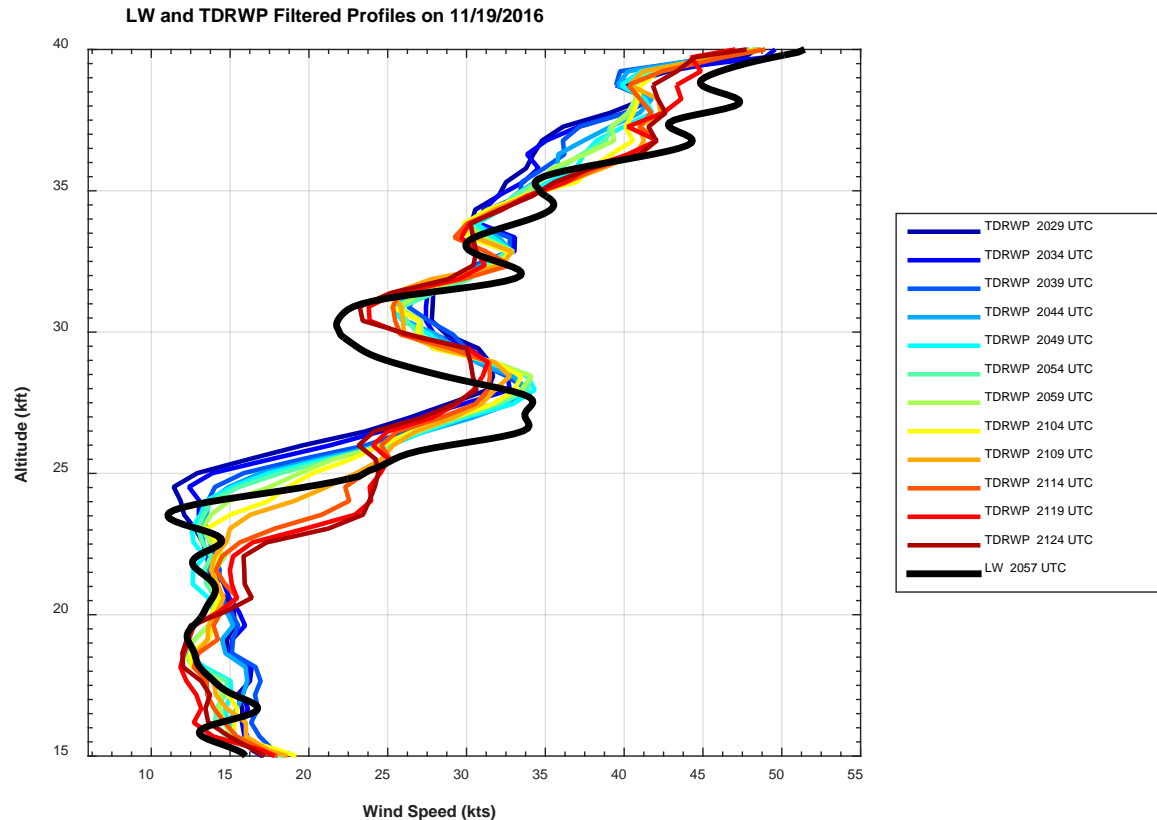


# Single Profile Comparison: 2137 UTC

Comparison Between LW at 11/19/2016 2137 UTC and TDRWP at 11/19/2016 2209 UTC



# Multiple Profile Comparison: 2057 UTC with Filter



- Graph shows unfiltered TDRWP profiles within  $\frac{1}{2}$  hour of the 2057 UTC LW profile.
- Applied a low-pass filter with a 460 m (1509 ft) cutoff wavelength to all TDRWP and LW profiles.